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RESEARCH ON INTELLIGENT SYNTHESES ENVIRONMENTS

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NATIONAL AERONAUTICS and SPACE ADMINISTRATION
NASA Langley Research Center
Hampton, Virginia 23664

Attention:

Dr. John J. Rehder
Systems Engineering Competency
NASA Langley Research Center
Hampton, Virginia

Submitted by

Ahmed K. Noor
William E. Lobeck Professor of Aerospace Engineering,

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Center for Advanced Engineering Environments
College of Engineering and Technology
Old Dominion University

Research on Intelligent Synthesis Environment

Old Dominion University
NASA Langley Research Center, Hampton, Virginia

Abstract

Four research activities related to Intelligent Synthesis Environment (ISE) have been performed under this grant. The four activities are: 1) non-deterministic approaches that incorporate technologies such as intelligent software agents, visual simulations and other ISE technologies; 2) virtual labs that leverage modeling, simulation and information technologies to create an immersive, highly interactive virtual environment tailored to the needs of researchers and learners; 3) advanced learning modules that incorporate advanced instructional, user interface and intelligent agent technologies; and 4) assessment and continuous improvement of engineering team effectiveness in distributed collaborative environments.

The principal investigator for these research activities is Dr. Ahmed K. Noor, William E. Lobeck Professor of Aerospace Engineering, and Director of the Center for Advanced Engineering Environments. The co-investigator is Dr. R. Bowen Loftin, Professor of Electrical and Computer Engineering, and Professor of Computer Science. The NASA Langley monitors are Ms. Kimberly A. Cannon and Dr. John J. Rehder then with the Intelligent Synthesis Environment Program Office, NASA Langley Research Center.

Summary of the Research Activities

The four activities performed under this grant during the period April 1, 2001 to September 30, 2002, are applications of the new paradigm of collaborative distributed research that aims at synergistic coupling of several technologies. The results are contained in six publications and four multimedia presentations, and are summarized subsequently. The list of publications and presentations are given in Appendix 1.

1. Non-deterministic Approaches

There has been a growing realization among engineers that unavoidable uncertainties in geometry, material properties, boundary conditions, loading, operational environment, modeling, and analysis assumptions must be taken into account to produce meaningful designs. Three categories of approaches for handling uncertainty can be identified, depending on the type of uncertainty and the amount of information available about the system characteristics and the operational environment. The three categories are probabilistic analysis, fuzzy-logic approaches, and set theoretical, convex (or anti-optimization) approaches. In probabilistic analysis, the system characteristics and/or source variables are assumed to be random variables (or functions), and the joint probability density functions of these variables are selected. The main objective of the analysis is the determination of the reliability of the system.

If the uncertainty is because of vaguely defined system and/or operational characteristics, imprecision of data, and subjectivity of opinion or judgment, fuzzy logic-based treatment is appropriate. Randomness describes the uncertainty in the occurrence of an event. Fuzziness describes the ambiguity of the event. When the information about the system and/or operational characteristics is fragmentary (i.e., only a bound on the maximum possible response function is known), then convex modeling can be used. Convex modeling produces the maximum or least-favorable response and the minimum or most-favorable response of the system under the constraints within the set-theoretical description.

A workshop was organized to identify the potential and the implementation process of non-deterministic approaches research network which couple non-deterministic approaches with technologies such as intelligent software agents, visual simulation and other ISE technologies. The workshop also addressed partnerships with universities and industry needed to apply these technologies to the reliability and risk assessment of future generation reusable launch vehicles. The proceedings of the workshop have been published.

2. Virtual Laboratories

The virtual labs developed under this grant leveraged modeling, simulation, information and other ISE technologies to create immersive, highly interactive virtual environment tailored to the needs of researchers and learners. Virtual experiments in the virtual labs are not exact duplicates of their real-world counterparts and, therefore, can provide educationally valuable features not available in physical experiments (for example, a fatigue test can be simulated in a few minutes). Two virtual labs were constructed as proof-of-concept test beads for two unique NASA test facilities, namely, the 14 x 22 wind tunnel and the aircraft landing dynamics facility.

The research-oriented virtual labs developed can be used for any combination of the following:

- Visualization of the computer model of the test facility. The user can walk/fly-through the virtual lab.

- Visualization of the results of the experiment. These include graphs of various response quantities such as applied load vs. strain at various points for structures testing machines. Pre-stored results can be displayed. The VE allows viewing of the results from any angle, zooming on a desired feature, and replaying the results at any speed.

- Visual simulation of the physical experiment. The simulation results displayed can include more information than the test measurements provide. For structures testing machines, a structures finite element code can perform a dynamic simulation of the machine/specimen multi-body system. Animations of the test with the specimen color shaded using stress, strain and other response quantities can be displayed. In wind tunnel tests, CFD codes can predict the response time history of the pressure, temperature, and velocity fields in the fluid. The simulation results can include shaded stream and streak lines, volume rendering of pressure, velocity, or temperature fields, volume arrow plots, and shaded cross-sections of the fluid domain. The VE allows viewing of the results from any angle, zooming in on a desired feature, and replaying the results at any speed. Numerical simulations can provide more information about the response than experimental measurements. This helps in the design of the experiment by placing the instruments and sensors in critical regions.

- Comparing the experiment measurements with the predictions of numerical simulations. The response measured from the experiment and that predicted using numerical simulations can be superimposed, placed side by side, or subtracted.

- Hybrid experimental and numerical modeling. For example, a component of an aerospace vehicle can be tested in the actual lab, while the other components of the vehicle can be numerically modeled.

- Computational steering. If the response of the machine or wind tunnel can be predicted at a "reasonable" speed, then the dynamic response can be continuously predicted as the user is interacting with the VE. Thus, the effect of changing the shape and/or parameters of the virtual model can be studied in real time. DIS simulations can be run from within the VE. The user can dynamically change the problem parameters, such as the applied load, while observing the simulation results.

- Training and education. The VE can simulate the actual operation of the physical test facility, including buttons, gauges, knobs, etc. These objects can mimic the response of the physical objects. Thus, the VE can be used for risk free training and preparation for the experiment. In addition, an intelligent agent can guide a user through each test step and can provide tips on what to look for in order to gain a better understanding of the test.

3. <u>Advanced Learning Modules</u>

The research on advanced learning modules combined a number of cutting edge technologies, including multi-modal and natural language communication, intelligent software agents, elaborate multimedia and visualization facilities. The module developed focused on integrated design process for reusable launch vehicles. It can be considered as part of the learning network and serves as a model for future learning modules that can be packaged into training, disciplinary and interdisciplinary courses.

The development of this research module was accomplished through partnership with experts from NASA Marshall and vendors specialized in intelligent software agents, natural language communication and other advanced human/computer interfaces. A proof-of-concept prototype was developed and distributed to NASA researchers and managers for evaluation.

4. <u>Assessment and Continuous Improvement of Engineering Team Effectiveness in Distributed Collaborative Environments</u>

A detailed review of the literature of team performance was conducted and an assessment of this literature from the standpoint of distributed teams engaged in engineering design and analysis was performed. The results of this effort are documented in Annex A (A Review of Key Team Performance Processes: Implications for Engineering in Distributed Collaborative Environments).

During August 2001, the research team observed the ISAT within the context of a specific project. The results of these observations are contained in Annex B (Team Task Analysis of ISAT – Inter-center Systems Analysis Team).

Based on both the literature review and the ISAT observations, an engineering team project model for a distributed collaborative environment was developed. This product is included in Annex C (Development and Assessment of an Engineering Team Process Model in Distributed Collaborative Environment: The Case of ISAT).

Following the development of the model described in Annex C, the model and the results of the ISAT observations recorded in Annex B were used to prepare a final recommendation for the use of distributed collaborative environments for engineering design and analysis. The recommendation was further refined to specifically apply to the ISAT environment in use within NASA. Annex D (Virtual Collaborative Environments for System of Systems Engineering and Applications for ISAT) documents this recommendation.

In addition to the four products contained in the annexes to this report, at least one journal publication is anticipated as a result of this research. In addition, a portion of the work reported here serves as the basis for the master's thesis of a student at Old Dominion University.

Appendix I
Publications and Presentations

Publications

1. Noor, Ahmed K. and Wasfy, Tamer M., "Simulation of Physical Experiments in Immersive Virtual Environments", *Engineering Computations*, Vol. 18, No. 3/4, 2001, pp. 515-538.

2. Wasfy, Tamer M. and Noor, Ahmed K., "Visualization of CFD Results in Immersive Virtual Environments", *Advances in Engineering Software*, Vol. 32, No., pp. 717-730, 24 August 2001.

3. Wasfy, Tamer M. and Noor, Ahmed K., "Ruled-Based Natural-Language Interface for Virtual Environments", *Advances in Engineering Software*, , Vol. 33, No. 3, pp. 155-168, March 14, 2002.

4. Noor, Ahmed K. (complier), Nondeterministic Approaches and Their Potential for Future Aerospace Systems, *NASA CP-2001-211050*, September 2001.

5. Dryer, David A., "Virtual Collaborative Environments for System of Systems Engineering and Applications for ISAT", November 2002.

6. Fletcher, Thomas D. and Major, Debra A., "A Review of Key Team Performance Processes: Implications for Engineering in Distributed Collaborative Environments", November 2002.

Multimedia Presentations by A. K. Noor

1. "*Future Research and Learning Networks*", invited keynote address, Army/NASA Simulation and Modeling for Acquisitions, Requirements and Training (SMART) Conference, Kissimmee, FL, April 18, 2001.

2. "*Trends and Future Directions in Uncertainty Management, Reliability, and Risk Assessment*", invited keynote lecture, 5th Annual FAA/Air Force/NASA/Navy Workshop on the Application of Probabilistic Methods to Gas Turbine Engines, Cleveland, OH, June 11, 2001.

3. "*Reengineering University Education*", keynote lecture, First MIT Conference on Computational Fluid and Solid Mechanics, Cambridge, MA, June 12, 2001.

4. "*Pathway to Our Future Engineering Workforce*", keynote lecture, Teaching Tools 2001, Syracuse University, NY, October 11, 2001, [http://www.i2sports.com/events/2001q4/nasa/].